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Light Diffraction Using Periodical Texture of Nematic Liquid Crystal Induced by Elastic Wave

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1. Introduction

An acoustooptic effect using nematic liquid crystal has been observed by means of surface acoustic wave (SAW) propagation[1-3]. The SAW is usually excited by an interdigital transducer (IDT) and the transducer performance is limited to one frequency region because of its single-mode operation. On the other hand, a Lamb wave propagating in a thin plate with two free surfaces is available for multiple-modes operation[4]. The IDT on a thin piezoelectric ceramic plate is useful for exciting elastic waves into a nonpiezoelectric substrate such as a transparent glass plate. In this study, we have observed two kinds of periodical textures in a nematic liquid crystal layer, induced by the elastic waves propagating in the glass substrate composing a liquid crystal cell. Light diffraction characteristic utilizing the periodical texture has been also reported.

2. Experimental Procedure

Figure 1 shows a schematic structure of the liquid crystal cell used in this study. The transducer substrate is a thin piezoelectric ceramic plate (TDK, 101A) with a thickness of 250μm and have the poling axis in the thickness direction. The IDT has an interdigital periodicity of 400μm and seven electrode-finger pairs. The elastic waves excited by applying an electrical signal to the IDT propagate in the liquid crystal cell layer. A liquid crystal sample is sandwiched between two indium-tin oxide (ITO) coated glass plates (Corning, 7059). A homogeneous aligned cell was prepared by using glass plates whose surfaces were coated with polyimide (JSR, AL1254) and rubbed unidirectionally. Texture observation of the nematic liquid crystal layer was carried out using a polarizing microscope (Nikon, OPTIPHOT2-POL) under the existence of the elastic wave propagating in the glass plate and the texture images were recorded through a digital camera (Minolta, RD-175).

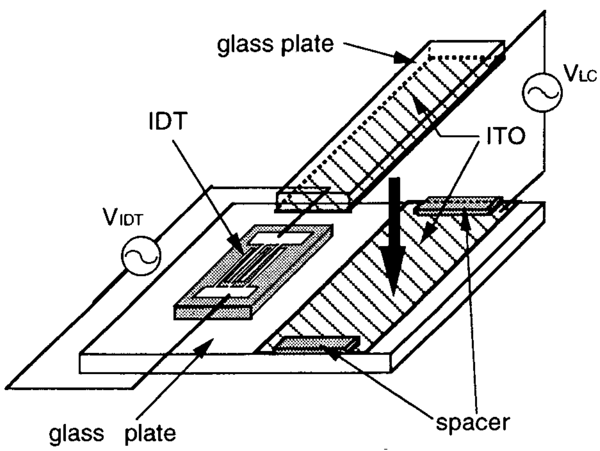

Fig.1. Schematic strucutre of liquid crystal cell.

3. Results and Discussion

Figure 2 shows an observed polarizing micrograph of the texture of nematic liquid crystal under elastic wave propagation. Two periodical textures are recognized in this figure. The longer periodical texture is clearly observed in the direction perpendicular to the propagation of the elastic wave, while the shorter periodical texture is observed in the longer periodical texture[5]. Polarizing micrographs of several shorter periodical textures are shown in Fig. 3 corresponding to the rubbing directions of 0°, 45° and 90° to the propagation direction of the elastic wave. From these figures, it is confirmed that the direction of the shorter periodical texture is determined by the orientation direction of the liquid crystal, which is determined by the rubbing direction.

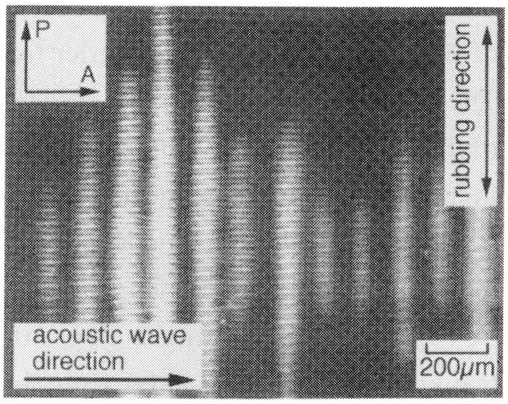

Fig.2. Polarizing micrograph of liquid crystal texture during elastic wave propagation.

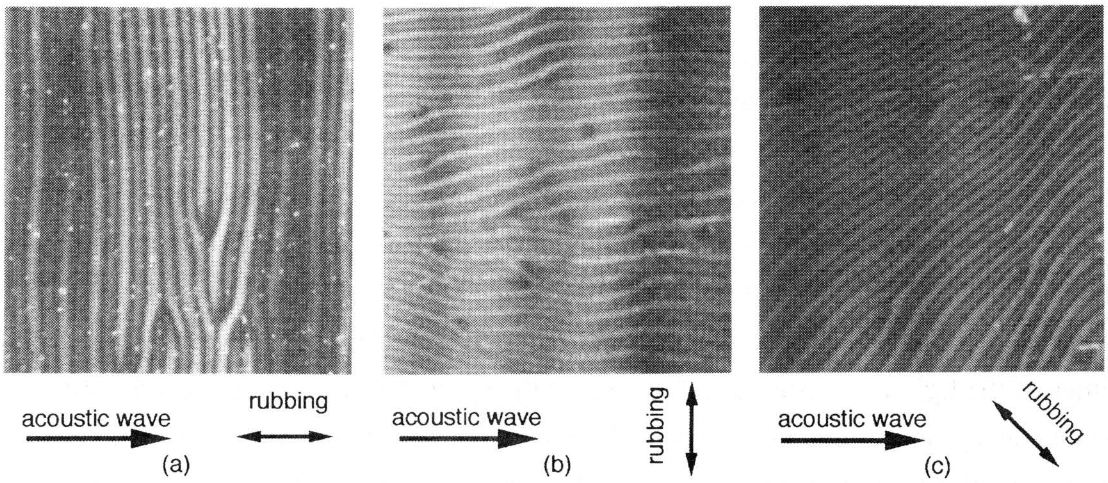

Fig.3. Polarizing micrographs of shorer periodical texture of liquid crystal induced by elastic wave propagation. Molecular orientation directions are (a) 0°, (b) 90° and (c) 45° to propagation direction of elastic wave.

A Williams domain was observed when applying an ac voltage with a low frequency to a homogeneously aligned cell of nematic liquid crystal with negative dielectric anisotropy[6]. This domain was formed to be perpendicular to the orientation direction of the liquid crystal molecules. The period of this domain agrees with the thickness of the liquid crystal layer. Figure 4 shows the observed period of the shorter periodical texture as a function of the thickness

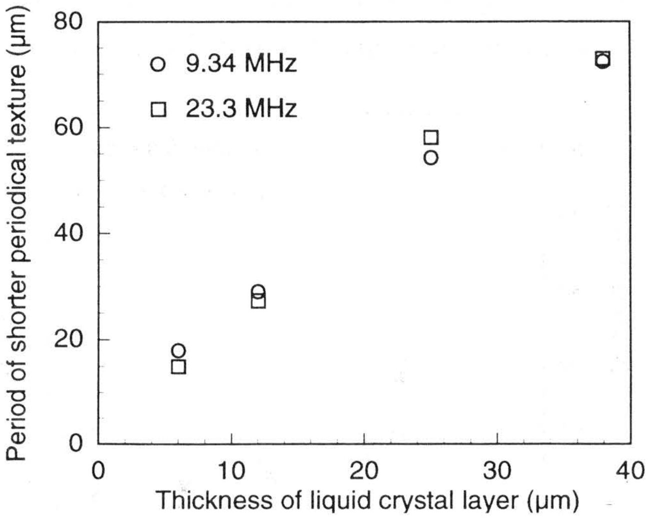

Fig.4. Measured periodical lentgt of shorter periodical texture as function of thickness of liquid crystal layer.

of the liquid crystal layer, under the propagation of the elastic wave for two carrier frequencies. The result is independent of the carrier frequency of the elastic wave. The measured period increases with increasing the thickness of the liquid crystal layer which is about twice of that of Williams domain.

Figure 5 shows angle dependences of transmitted and diffracted light intensities through the liquid crystal cell under the conditions with and without the elastic wave propagation. A diffraction peak is recognized at ±1.8° in this figure. The diffraction angle corresponds to the period of the shorter periodical texture. The diffraction is recognized in perpendicular to the shorter periodical texture. These results support that this light diffraction is caused by the shorter periodical texture.

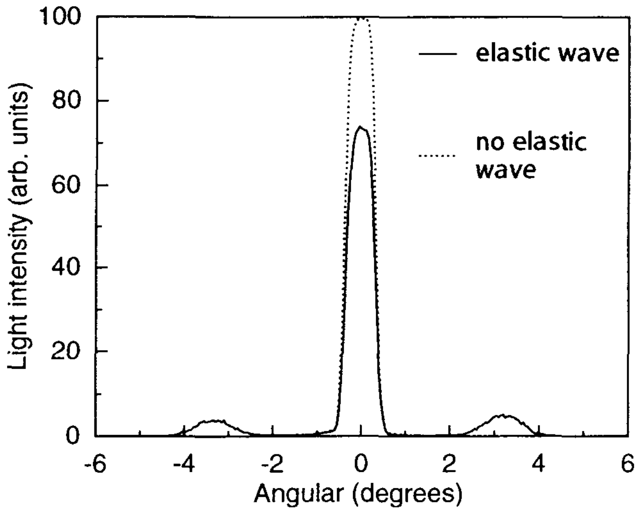

Fig.5. Angule dependences of transmitted and diffracted light intensity under conditions with and without elastic wave propagation.

In the nematic liquid crystal with positive dielectric anisotropy, the liquid crystal molecules are reorientated in the direction of the applied electric field. Therefore, the shorter periodical texture can be disappeared by the application of the electric field to the liquid crystal. Figure 6 shows the rise and decay times of the light diffraction as a function of the applied voltage to the liquid crystal cell. The rise time and decay times of an electrooptic effect in twisted nematic liquid crystal are also shown in this figure. The decay time, corresponding to the disappearance of the shorter periodical texture, decreases with increasing the applied voltage. This response time agrees with the that of the twisted nematic electrooptic effect. On the other hand, the rise time, corresponding to the formation of the shorter periodical texture, is independent of the applied voltage, while the response time is about twenty times longer than that of twisted nematic effect.

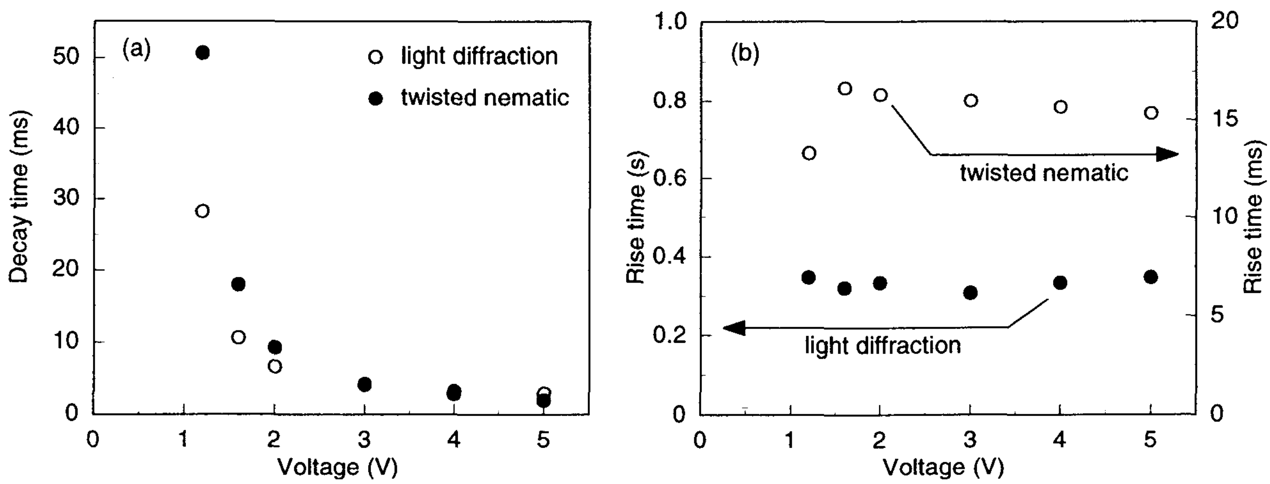

Fig.6. Applied voltatge dependences of (a) decay time and (b) rise time of light diffraction induced by elastic wave propagation and electrooptic effect of twisted nematic liquid crystal.

4. Summary

A nematic liquid crystal cell was mounted on a transparent glass plate in order to interact with elastic wave propagation. Two types of periodical textures were observed in the cell of nematic liquid crystal, induced by the existence of the elastic wave. The shorter periodical texture is independent of the carrier frequency of the elastic wave but is influenced by the layer thickness of liquid crystal. The light diffraction using the shorter periodical texture was observed. This diffraction was controlled by the application of the electric field to the liquid crystal layer. The response time of the disappearance of the diffraction under the application of the electric field depends on the field strength and was similar to the response time of the electrooptic effect of twisted nematic liquid crystal.

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